BIOLOGICAL CONTROL

Effect of Prey Density on the Functional and Numerical Responses of Two Species of Predaceous Mites (Acari: Phytoseiidae)

Paulo R. Reis[1], Elber O. Sousa[2], Adenir V. Teodoro[2] and Marçal Pedro Neto[2]

[1]*EPAMIG-CTSM/EcoCentro, C. postal 176, 37200-000, Lavras, MG, e-mail: paulo.rebelles@epamig.ufla.br*
[2]*Universidade Federal de Lavras, C. postal 37, 37200-000, Lavras, MG*

Neotropical Entomology 32(3):461-467 (2003)

Efeito da Densidade de Presa nas Respostas Funcional e Numérica de Duas Espécies de Ácaros Predadores (Acari: Phytoseiidae)

RESUMO - Ácaros da família Phytoseiidae são os inimigos naturais de ácaros-praga mais importantes e estudados. Uma questão freqüentemente levantada é se os fitoseídeos podem reduzir altas densidades de ácaros fitófagos a baixos níveis. Os estudos da resposta funcional e numérica podem contribuir para responder essa pergunta. O objetivo deste trabalho foi avaliar o potencial de predação de *Iphiseiodes zuluagai* Denmark e Muma e *Euseius alatus* DeLeon (Acari: Phytoseiidae) como agentes de controle biológico do ácaro fitófago *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae), vetor do vírus da leprose-dos-citros e da mancha-anular do cafeeiro. Bioensaios foram realizados em laboratório. Fêmeas adultas de cada predador foram individualizadas em arenas de folha de citros com 3 cm de diâmetro. Fases imaturas de *B. phoenicis* foram oferecidas, como presas, nas seguintes quantidades/arena: 1, 2, 5, 10, 20, 30 e 35 (com sete repetições), 45 (quatro repetições), 55 (três repetições) e 70, 100, 125, 200 e 300 (duas repetições). O número de presas mortas e de ovos colocados pelo predador foram avaliados a cada 24h, durante oito dias. As presas mortas foram diariamente substituídas por novas presas. Para ambos os ácaros predadores foi constatada uma correlação positiva e altamente significativa entre o número de presas oferecidas e mortas. A oviposição média diária também aumentou em função do número de presas mortas. Nas densidades mais baixas, *E. alatus* matou mais *B. phoenicis* do que *I. zuluagai*, e o contrário foi observado nas densidades mais altas. É possível que *E. alatus* possa reduzir a população de *B. phoenicis* mesmo em baixas densidades do ácaro fitófago, e que *I. zuluagai* possa fazer o mesmo nas mais altas. O fato de *E. alatus* necessitar de menos presas que *I. zuluagai* sugere que sua sobrevivência possa ser maior do que a de *I. zuluagai* sob baixa densidade de presa.

PALAVRAS-CHAVE: *Iphiseiodes zuluagai, Euseius alatus, Brevipalpus phoenicis,* citros, cafeeiro

ABSTRACT - Phytoseiidae mites are the most important and studied natural enemies of pest mites. A question frequently raised is whether phytoseiid may reduce high densities of phytophagous mites. Studies of functional and numerical responses may help to answer this question. The aim of this work was to evaluate the potential predation success of *Iphiseiodes zuluagai* Denmark and Muma and *Euseius alatus* DeLeon (Acari: Phytoseiidae) on *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae), vector of the citrus leprosis and the coffee ringspot viruses. Bioassays were performed in the laboratory. Adult females of each predator were isolated in arenas made with citrus leaves (3-cm diameter). Immature stages of *B. phoenicis* were offered as prey, at the following numbers/arena: 1, 2, 5, 10, 20, 30 and 35 (seven replicates), 45 (four replicates), 55 (three replicates) and 70, 100, 125, 200 and 300 (two replicates). The number of killed prey and of eggs laid by the predators was evaluated every 24h, during eight days. Killed prey was replaced daily by new prey. For both predatory mites, a positive and highly significant correlation was found between the numbers of prey offered and killed. The average daily oviposition rate also increased with the number of killed prey. At the lower densities, *E. alatus* killed and ate more *B. phoenicis* than *I. zuluagai*. The opposite was observed at the highest densities. It is possible that *E. alatus* can reduce *B. phoenicis* population even at low prey densities, and *I. zuluagai* can do the same also at high densities. The fact that *E. alatus* requires less prey than *I. zuluagai* suggests that its survivorship may be higher than that of *I. zuluagai* at low prey densities.

KEY WORDS: *Iphiseiodes zuluagai, Euseius alatus, Brevipalpus phoenicis,* citrus, coffee plant

Mites of the family Phytoseiidae are the most important and studied natural enemies of pest mites (McMurtry *et al.*1970, Moraes 1991). *Iphiseiodes zuluagai* Denmark & Muma is one of the most frequent and abundant phytoseiid predators occurring on citrus and coffee trees in Brazil (Pallini Filho *et al.* 1992, Reis *et al*. 2000b). *I. zuluagai* is most abundant during periods of low rainfall (Sato *et al.* 1994, Reis *et al*. 2000b) when the population of the leprosis or ringspot mite, *Brevipalpus phoenicis* (Geijskes), is also high on citrus (Oliveira 1986) and coffee (Pallini Filho 1991). The phytoseiid *Euseius alatus* DeLeon is most abundant in the rainy season (Reis *et al*. 2000b) coinciding with the highest levels of the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) (Caetano & Oliveira 1975).

An issue frequently raised is whether phytoseiids may reduce high densities of phytophagous mites. Studies of functional response (prey numbers killed by unit of time) and numerical response (produced offspring per unit time or other change in predator density) may help to answer this question (Solomon 1949, Mori & Chant 1966, Laing & Osborn 1974).

Holling (1959) states that, in general, three basic types of functional response to prey density are identified: linear, convex and sigmoid. In linear response (called type I), the number of consumed prey rises linearly up to a plateau; in convex response (type II), the number of consumed prey rises with prey density but begins to decrease when reaching a maximum point (dome shape curve). In other words, prey consumption reduces at highest prey densities, and in the sigmoid response (type III), predation results into a sigmoid shape response, with increasing prey densities. The first type of response is supposedly typical of aquatic filter-feeding invertebrates; the second type, of predator and parasitoid arthropods (invertebrates) and the third type, of vertebrate predators (Hassel 1978).

Interrupting a predator during its feeding may result in increased prey mortality (Hoyt & Caltagirone 1971 cited by Laing & Osborn 1974). Interrupting a predator during search or capture of prey can, on the other hand, result in poor predation. Interrupting the rest period of a predator can start both search and feeding behavior or stimulate other behaviors such as running away or hiding, which may result in further demand of energy, with subsequent effects on the numerical and functional responses. All these interruptions have been called "interference" when negative to the functional and numerical responses of predators, and "stimulation", when positive to these responses. Increased number of prey killed at the highest densities is due to the "interference-stimulation" component, directly or indirectly interfering with the predator (Sandness & McMurtry 1970). According to these authors, the predator's size, relative to their prey, is an important factor in predation efficiency. Large prey can inhibit the predator more aggressively when at high density.

The number of adult prey killed may decrease at high densities, because the eggs laid by the prey are preferred for consumption (Santos 1975) or because of increased disturbance by the prey (Mori & Chant 1966). Santos (1975) showed that the sort of response depends on prey stage. So, for eggs and males of *Tetranychus urticae* Koch (Tetranychidae) as food for the phytoseiid *Neoseiulus fallacis* (Garman), the corresponding curve was type I and for females as food, it was type II. The author justifies, for the second case, that predation decrease at high densities is also due to preferred predation of eggs as compared to predation on the bulky and active females that laid them. The author concluded that both predation and predator egg deposit rate depend on prey density. The feeding increase rates are ascribed to the "interference-stimulation" component, which interferes in the predator's standard activity. At low prey densities, the predator was observed spending time resting after feeding or laying eggs. At high densities the prey often bump with the predator. Only with eggs as prey, the "interference-stimulation" component was not observed and no increase in egg predation was noticed at the high densities. Predator oviposition increase, due to predation, was also found by Smith & Newsom (1970) with *N. fallacis*, having the tetranychid mites, *Tetranychus yusti* McGregor, *Tetranychus desertorum* Banks and *T. urticae*, as prey.

Based on these observations, this work aimed to evaluate the potential of biological control of two predatory phytoseiid mite species, *I. zuluagai* and *E. alatus*, preying on the phytophagous mite *B. phoenicis* through the study of the functional and numerical responses.

Material and Methods

The bioassays were performed at the Acarology Laboratory (at 25 ± 2ºC, 70 ± 10% of RH and 14h of photophase) of Centro Tecnológico do Sul de Minas - CTSM / Centro de Pesquisa em Manejo Ecológico de Pragas e Doenças de Plantas - EcoCentro, of Empresa de Pesquisa Agropecuária de Minas Gerais - EPAMIG, Campus of the Universidade Federal de Lavras - UFLA, Lavras, Minas Gerais.

Stock Colonies of Predatory and Prey Mites

Phytoseiid mites. The phytoseiid maintenance rearing was started with mites collected from a citrus orchard, in Lavras, Minas Gerais State, and a month before starting the work. Mites were identified based on Denmark & Muma (1972), Aponte & McMurtry (1995) and DeLeon (1966). The stock colonies were established on arenas prepared with 6-cm diameter flexible plastic sheet discs, floating on water, and castor bean pollen (*Ricinus communis* L.) as food for the mites (Reis & Alves 1997).

B. phoenicis. Stock colonies of *B. phoenicis*, used as prey, were started with mites collected from a 'Catuaí' coffee crop, in Lavras County, a month before starting the work. The rearing unit consisted of citrus fruits, with lesions of scab disease, caused by *Elsinoe australis* Bit. & Jenk.; the lesions served as shelter and egg laying sites. The citrus fruits were covered with a layer of paraffin for impermeability, leaving uncovered only a circle (3cm diameter), where the mites would later be placed. This circle was cleaned with a brush to remove contaminants and surrounded with a thin layer of a sticky substance (BioStick®) (Chiavegato 1986).

Bioassays

An adult female of each phytoseiid species, in independent bioassays, was confined for eight days in a 3-cm diameter arena, made with citros leaves, floating in distilled water inside a 15-cm diameter by 2-cm depth Petri dish. Eight arenas were placed equidistantly from the other in each petri dish, as described by Reis *et al*. (1998). Both, larvae and nymphs of *B. phoenicis* were used as prey because those seem to be the stage preferred by *Euseius citrifolius* Denmark & Muma (Gravena *et al.* 1994), *E. alatus* and *I. zuluagai* phytoseiids (Reis *et al.* 2000a). The prey was placed at the following numbers/arena: 1, 2, 5, 10, 20, 30 and 35 (seven replicates), 45 (four replicates), 55 (three replicates) and 70, 100, 125, 200 and 300 (two replicates). As a check, arenas were maintained with the same densities of prey mites, without predators, for observation of the natural mortality.

The numbers of prey killed and of eggs laid by the predators were evaluated daily for eight days, removing at the same time the eggs laid by the predators and, replacing dead by live prey.

Results and Discussion

The maximum natural mortality of *B. phoenicis* observed in the check treatments, with all densities of prey mites, was of only 12.5% in the tests with *I. zuluagai* and 8.6% with *E. alatus*. These results demonstrated that the largest cause of mortality of prey mites was really the predation by phytoseiids.

I. zuluagai. The number of *B. phoenicis* killed in a day by this predator increased as a function of the number of prey provided mites, reaching a maximum percentage of predation around 55 mites/day or 7.7 mites/cm^2 (Table 1 and Fig. 1). At the two lowest densities, the percentage of prey consumption was low, perhaps due to the difficulty faced by the predator in finding the prey. A positive and highly significant correlation was observed between the numbers of prey provided and killed (Table 1 and Fig. 2).

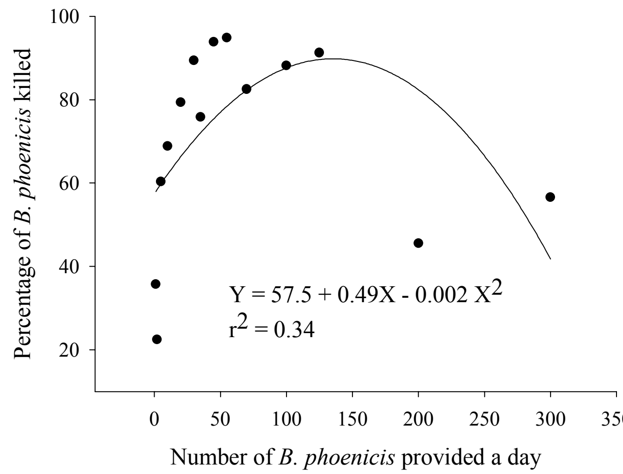

Figure 1. Percentage of *B. phoenicis* preyed on by a female of *I. zuluagai* according to the provided density.

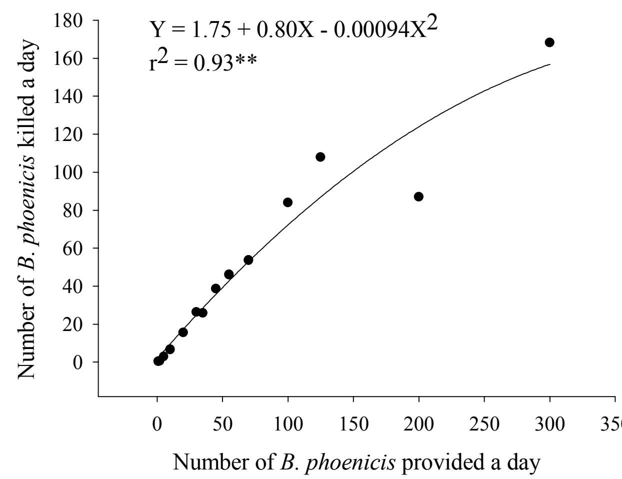

Figure 2. Number of *B. phoenicis* preyed on by a female of *I. zuluagai* according to the provided density.

Table 1. Predation capacity of *I. zuluagai* at different densities of the prey, *B. phoenicis*, kept at 25 ± 2ºC, 70 ± 10% RH and 14h photophase.

Number of provided prey	Number (mean ± SE / day)		Percentage		
	Prey killed	Partial prey consumption	Prey killed	Partial prey consumption	Prey not killed
1	0.4 ± 0.03	0.0 ± 0.00	35.7	0.0	64.3
2	0.4 ± 0.10	0.0 ± 0.00	22.5	0.0	77.5
5	3.0 ± 0.08	0.0 ± 0.00	60.4	0.0	39.6
10	6.7 ± 0.49	0.0 ± 0.00	68.8	0.0	31.2
20	15.6 ± 0.87	0.0 ± 0.00	79.3	0.0	20.7
30	26.4 ± 1.00	0.0 ± 0.00	89.4	0.0	10.6
35	25.9 ± 1.44	0.0 ± 0.00	75.8	0.0	24.2
45	38.7 ± 1.21	0.0 ± 0.00	93.9	0.0	6.1
55	46.1 ± 1.10	0.0 ± 0.00	94.9	0.0	5.1
70	53.8 ± 2.71	0.4 ± 0.18	82.5	0.6	16.9
100	84.0 ± 2.22	3.9 ± 1.04	88.2	4.1	7.7
125	107.8 ± 3.01	5.0 ± 1.47	91.3	4.2	4.5
200	87.0 ± 5.32	11.3 ± 1.28	45.5	5.9	48.6
300	168.2 ± 9.33	2.8 ± 0.87	56.6	1.7	41.8

Above 55 prey/arena (7.7 mites/cm^2), part of the mites attacked were only partially consumed (Table 1), perhaps due to the component "interference-stimulation" already reported by several authors (Mori & Chant 1966, Sandness & McMurtry 1970). The absence of these component can be responsible for the low percentage of predation that happened at the low densities, in other words, the predators, which did not have any contact with their prey, were not stimulated to prey upon others. At the highest studied densities (200 and 300 prey/arena) the percentage of predation was also smaller, and the explanation can be given by the same component, and in that case there was excessive disturbance of the predatory mites by the phytophagous mites. Except for the two smaller densities and 200 prey/arena, the percentage of killed prey was always larger than the one of not killed (Table 1).

The number of eggs laid/day increased as a function of prey killed, with a positive and highly significant correlation (Table 2 and Fig. 3). Chant (1961) also observed similar results for *Galendromus occidentalis* (Nesbitt), Smith & Newsom (1970) for *N. fallacis* and Laing & Osborn (1974) for *Phytoseiulus persimilis* Athias-Henriot, *G. occidentalis* and *Neoseiulus chilenensis* (Dosse) fed on tetranychids.

Table 2. Functional and numerical responses of the predator mite *I. zuluagai* having as prey the mite *B. phoenicis* at several densities.

Number of provided prey	Number (mean ± SE/day)	
	Prey killed	Eggs laid by predator
1	0.4 ± 0.03	0.1 ± 0.01
2	0.4 ± 0.10	0.1 ± 0.04
5	3.0 ± 0.08	0.2 ± 0.05
10	6.7 ± 0.49	0.2 ± 0.06
20	15.6 ± 0.87	0.3 ± 0.06
30	26.4 ± 1.00	0.3 ± 0.06
35	25.9 ± 1.44	0.3 ± 0.06
45	38.7 ± 1.21	0.5 ± 0.09
55	46.1 ± 1.10	0.5 ± 0.10
70	53.8 ± 2.71	0.6 ± 0.13
100	84.0 ± 2.21	0.9 ± 0.18
125	107.8 ± 3.01	0.9 ± 0.17
200	87.0 ± 5.32	1.1 ± 0.18
300	168.2 ± 9.33	0.4 ± 0.13

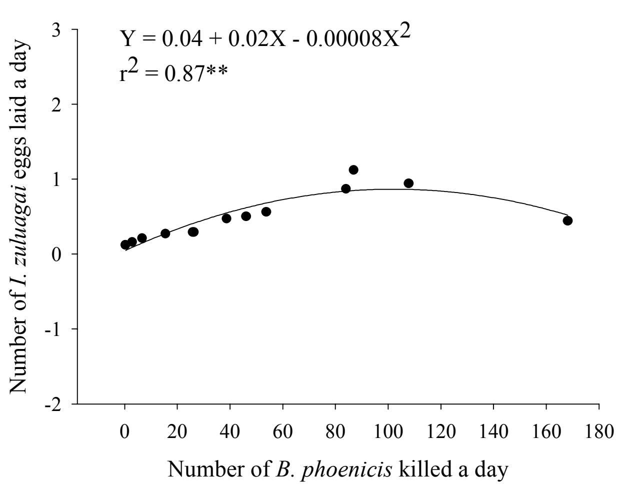

Figure 3. Number of eggs laid by a female of *I. zuluagai* according to the prey, *B. phoenicis*, killed.

Considering the obtained results, it is possible that *I. zuluagai* can reduce the population of *B. phoenicis* in field conditions, even if this reaches high densities. The mite *B. phoenicis* doesn't produce webs, and probably this fact may make predation easier, although according to McMurtry & Croft (1997) there are several species of Phytoseiidae frequently associated with species of Tetranychidae that produce dense webbing.

E. alatus. The number of *B. phoenicis* killed per day by this predator increased as a function of the number of prey provided, reaching a maximum percentage of consumption between 5 and 35 mites/day (0.7 and 4.9 mites/cm^2). This, the optimum prey density for *E. alatus* was considerably lower than that for *I. zuluagai.* At the lowest densities, *E. alatus* was more efficient in killing *B. phoenicis* than *I. zuluagai* (Table 3 and Fig. 4), possibly because of its larger mobility, observed in the bioassays. A positive and highly significant correlation was observed between the number of mites provided and killed (Fig. 5). The partial consumption of prey was starting from 35 prey/arena (4.9 mites/cm^2), a lower number than that found for *I. zuluagai* (55 prey/arena or 7.7 mites/cm^2), due perhaps to the component "interference-stimulation" and the larger mobility of *E. alatus*. At the densities above 100 prey/arena (14.1 mites/cm^2) the percentage of prey not killed was larger than the killed (Table 3). The lowest predation at the high densities is probably also due to the component "interference-stimulation", in this case by having excess of disturbance, which can lead the mite to reject the prey. The number of eggs laid/day by the predatory mite increased in function to the prey killed, having a positive and highly significant correlation to show an example of what was verified with *I. zuluagai* in this same work (Table 4 and Fig. 6). Considering the obtained results, it is possible that *E. alatus* can reduce the population of *B. phoenicis* in the field, even in low densities of the phytophagous mites.

The fact that *E. alatus* need less prey than *I. zuluagai* suggests that its survivorship can be better than the one of *I. zuluagai* under low prey density in the field. The higher aggressiveness of *I. zuluagai* than those of *E. alatus* in relation to kill *B. phoenicis* was also recorded by Reis *et al*. (2000a).

The functional response to prey density by *I. zuluagai* was linear (type I), where the number of killed prey rises linearly up to a plateau (Fig. 2) and by *E. alatus* was convex (type II), where the number of killed prey grows with the prey density but begins to decrease in reaching a maximum point (Fig. 5).

Type I curve was observed by Chant (1961) for the predatory mite *G. occidentalis*, feeding on *T. urticae*. For *P. persimilis*, also feeding on *T. urticae*, Mori & Chant (1966) found a type II response. In this case, predators were disturbed by prey, at high densities of the latter. Mori

Table 3. Predation capacity of *E. alatus* at different densities of the prey, *B. phoenicis*, kept at 25 ± 2ºC, 70 ± 10% RH and 14h photophase.

Number of provided prey	Number (mean ± SE / day)		Percentage		
	Prey killed	Partial prey consumption	Prey killed	Partial prey consumption	Prey not killed
1	0.7 ± 0.12	0.0 ± 0.00	67.9	0.0	32.1
2	1.4 ± 0.11	0.0 ± 0.00	70.5	0.0	29.5
5	4.0 ± 0.20	0.0 ± 0.00	83.8	0.0	16.2
10	7.8 ± 0.44	0.0 ± 0.00	78.5	0.0	21.5
20	15.6 ± 0.66	0.0 ± 0.00	79.2	0.0	20.8
30	19.9 ± 1.09	0.0 ± 0.00	67.0	0.0	33.0
35	27.0 ± 0.90	0.0 ± 0.00	77.2	0.0	22.8
45	29.9 ± 2.15	1.3 ± 0.52	71.1	3.0	25.9
55	24.6 ± 2.77	0.8 ± 0.49	49.0	1.6	49.4
70	34.3 ± 3.94	0.0 ± 0.00	50.2	0.0	49.8
100	40.1 ± 4.62	3.3 ± 1.24	40.6	3.3	56.1
125	48.2 ± 5.06	2.4 ± 0.93	40.3	2.0	57.7
200	45.4 ± 3.32	0.0 ± 0.00	24.1	0.0	75.9
300	33.2 ± 2.76	1.7 ± 0.42	11.1	0.6	88.3

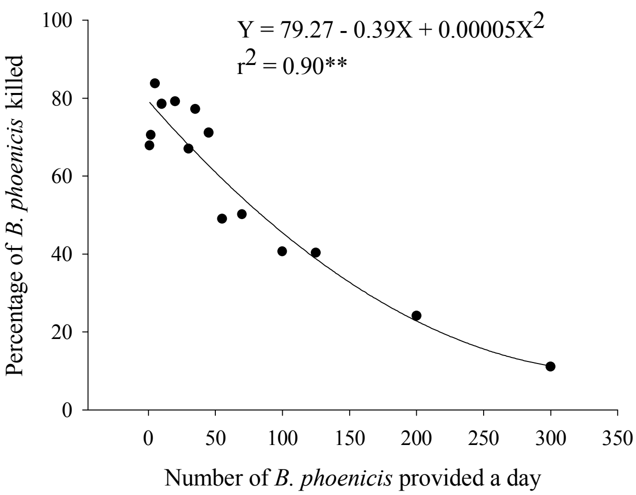

Figure 4. Percentage of *B. phoenicis* preyed on by a female of *E. alatus* according to the provided density.

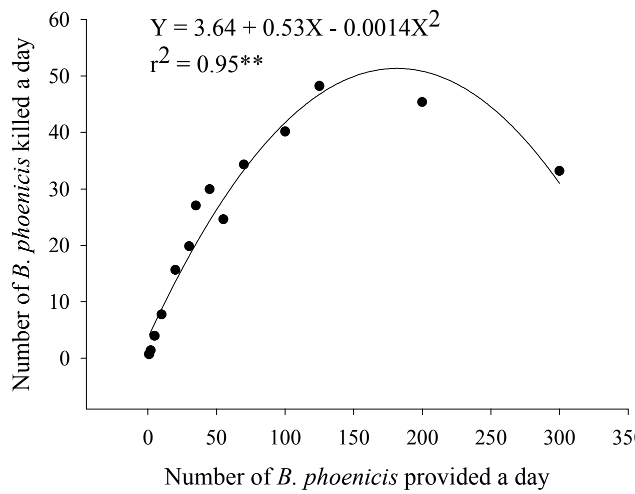

Figure 5. Number of *B. phoenicis* preyed on by a female of *E. alatus* according to the provided density.

& Chant (1966) suggested that high prey densities cause disturbance of phytoseiids and thus decrease its functional and/or numerical response. Sandness & McMurtry (1970) studied the functional response of the phytoseiids *Amblyseius largoensis* (Muma), *Euseius concordis* (Chant) and *Phytoseius floridanus* Muma fed on the tetranychid *Oligonychus punicae* (Hirst) and, they found that all species had type II response curve, with variations that were ascribed to an "interference-stimulation" process. It was also found that the three predators found and captured the prey even at the lowest densities, killing it even after satiated. Phytoseiids, even at high prey densities, are really affected by the hunger or satiation level, which causes attack-non-attack cycles. Type II response curve was also observed by Laing & Osborn (1974) for the phytoseiids *P. persimilis, G. occidentalis* and *N. chilenensis* feeding on *T. urticae*.

Although obtained in laboratory conditions, the results of this work allow to conclude that the phytoseiids *I. zuluagai* and *E. alatus* can be considered efficient predators of immature stages of *B. phoenicis*, at different densities of the prey, and to contribute for reduction of the prey mite population on citrus and coffee crops, where commonly they are present.

Acknowledgment

To Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG, Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq and to Consórcio Brasileiro de Pesquisa e Desenvolvimento do Café - CBP&D/Café for the financial support and scholarships granted.

Table 4. Functional and numerical responses of the predator mite *E. alatus* having as prey the mite *B. phoenicis* at several densities.

Number of provided prey	Number (mean ± SE/day)	
	Prey killed	Eggs laid by predator
1	0.7 ± 0.12	0.1 ± 0.07
2	1.4 ± 0.11	0.1 ± 0.04
5	4.0 ± 0.20	0.2 ± 0.05
10	7.7 ± 0.44	0.2 ± 0.05
20	15.6 ± 0.66	0.2 ± 0.05
30	19.7 ± 1.09	0.2 ± 0.06
35	27.0 ± 0.90	0.3 ± 0.07
45	29.9 ± 2.15	0.6 ± 0.11
55	24.6 ± 2.76	0.5 ± 0.12
70	34.3 ± 3.94	1.1 ± 0.22
100	40.1 ± 4.62	0.9 ± 0.26
125	48.2 ± 5.06	2.0 ± 0.13
200	45.4 ± 3.32	1.2 ± 0.19
300	31.7 ± 2.76	1.3 ± 0.24

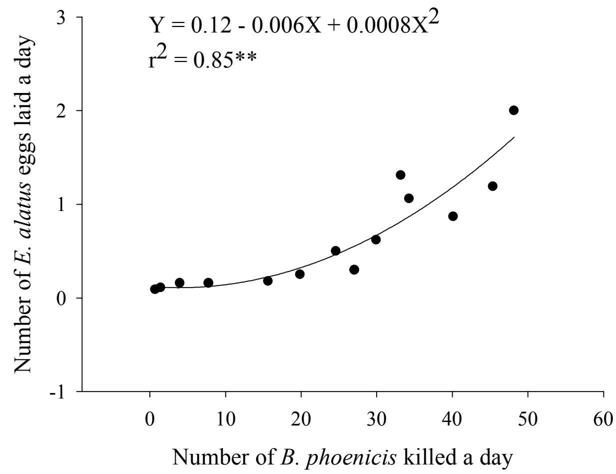

Figure 6. Number of eggs laid by a female of *E. alatus* according to the prey, *B. phoenicis*, killed.

Literature Cited

Aponte, O. & J.A. McMurtry. 1995. Revision of the genus *Iphiseiodes* DeLeon (Acari: Phytoseiidae). Int. J. Acarol. 221: 165-183.

Caetano, A.A. & C.A.L. Oliveira. 1975. Flutuação e controle da população do ácaro da falsa ferrugem *Phyllocoptruta oleivora* (Ashmead, 1879) na cultura de citros, p.247-257. In Congresso Brasileiro de Fruticultura, 3, Anais... Campinas, Sociedade Brasileira de Fruticultura, v.1, 338p.

Chant, D.A. 1961. The effect of prey density on prey consumption and oviposition in adults of *Typhlodromus (T.) occidentalis* Nesbitt (Acarina: Phytoseiidae) in the laboratory. Can. J. Zool. 39: 311-315.

Chiavegato, L.G. 1986. Biologia do ácaro *Brevipalpus phoenicis* em citros. Pesq. Agropec. Bras. 21: 813-816.

DeLeon, D. 1966. Phytoseiidae of British Guyana, with keys to species (Acarina: Mesostigmata). Studies on the fauna of Suriname and other Guyanas 8: 81-102.

Denmark, H.A. & M.H. Muma. 1972. Some Phytoseiidae of Colombia (Acarina: Phytoseiidae). Fla. Entomol. 55: 19-29.

Gravena, S., I. Benetoli, P.H.R. Moreira & P.T. Yamamoto. 1994. *Euseius citrifolius* Denmark & Muma predation on citrus leprosis mite *Brevipalpus phoenicis* (Geijskes) (Acari: Phytoseiidae, Tenuipalpidae). An. Soc. Entomol. Brasil 23: 209-218.

Hassel, M.P. 1978. The dynamics of arthropod predator-prey systems. Princeton, Princeton University Press, 237p.

Holling, C.S. 1959. The components of predation as revealed by a study of small-mammal predation of the European pine sawfly. Can. Entomol. 91: 293-329.

Laing, J.E. & J.A.L. Osborn. 1974. The effect of prey density on the functional and numerical response of three species of predatory mites. Entomophaga 19: 267-277.

McMurtry, J.A. & B.A. Croft. 1997. Life-styles of phytoseiid mites and their roles in biological control. Annu. Rev. Entomol. 42:291-321.

McMurtry, J.A., C.B. Huffaker & M. van de Vrie. 1970. Ecology of tetranychid mites and their natural enemies: A review. I. Tetranychidae enemies: their biological characters and the impact of spray practices. Hilgardia 40: 331-390.

Moraes, G.J. 1991. Controle biológico de ácaros fitófagos. Inf. Agropec. 15: 56-62.

Mori, H. & D.A. Chant. 1966. The influence of prey density, relative humidity and starvation on the predacious behavior of *Phytoseiulus persimilis* Athias-Henriot (Acarina: Phytoseiidae). Can. J. Zool. 44: 483-491.

Oliveira, C.A.L. 1986. Flutuação populacional e medidas de controle do ácaro da leprose *Brevipalpus phoenicis* (Geijskes, 1939) em citros. Laranja 7: 1-31.

Pallini Filho, A. 1991. Acarofauna e predação de ácaros fitófagos por ácaros predadores em cafeeiro (*Coffea arabica* L.) no Sul de Minas Gerais. Dissertação de mestrado, ESAL, Lavras, 91p.

Pallini Filho, A., G.J. Moraes & V.H.P. Bueno. 1992. Ácaros associados ao cafeeiro (*Coffea arabica* L.) no Sul de Minas Gerais. Ciênc. Prát. 16: 303-307.

Reis, P.R., A.V. Teodoro & M. Pedro Neto. 2000a. Predatory activity of phytoseiid mites on the development stages of coffee ringspot mite (Acari: Phytoseiidae, Tenuipalpidae). An. Soc. Entomol. Brasil 29: 547-553.

Reis, P.R. & E.B. Alves. 1997. Criação do ácaro predador *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae) em laboratório. An. Soc. Entomol. Brasil 26: 565-568.

Reis, P.R., L.G. Chiavegato & E.B. Alves. 1998. Biologia de *Iphiseiodes zuluagai* Denmark & Muma (Acari: Phytoseiidae). An. Soc. Entomol. Brasil 27: 185-191.

Reis, P.R., L.G. Chiavegato, E.B. Alves & E.O. Sousa. 2000b. Ácaros da família Phytoseiidae associados aos citros no município de Lavras, Sul de Minas Gerais. An. Soc. Entomol. Brasil 29: 95-104.

Sandness, J.N. & J.A. McMurtry. 1970. Functional response of three species of Phytoseiidae (Acarina) to prey density. Can. Entomol. 102: 692-704.

Santos, M.A. 1975. Functional and numerical response of the predatory mite, *Amblyseius fallacis* to prey density. Environ. Entomol. 4: 989-992.

Sato, M.E., A. Raga, L.C. Cerávolo, A.C. Rossi & M.R. Potenza. 1994. Ácaros predadores em pomar cítrico de Presidente Prudente, estado de São Paulo. An. Soc. Entomol. Brasil 23: 435-441.

Smith, J.C. & L.D. Newsom. 1970. Laboratory evaluation of *Amblyseius fallacis* as a predator of tetranychid mites. J. Econ. Entomol. 63: 1876-1878.

Solomon, M.E. 1949. The natural control of animal populations. J. Anim. Ecol. 18: 1-35.

Received 09/11/01. Accepted 23/08/03.